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Procedia Engineering 95 (2014) 172 – 177

Procedia Engineering

www.elsevier.com/locate/procedia

2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials 2014 (SCESCM 2014)

Strength reduction factor (R) and displacement amplification factor (Cd) of confined masonry wall with local brick in Indonesia

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Abstract

Indonesian local brick in the masonry wall with a cement-based mortar has different physical and mechanical characteristics from the developed countries that are always used as references. Because of the different behavior with another countries and low strength of local brick, it requires a lot of research to get the strength reduction factor (R) and the displacement amplification factor (Cd). It is important in order that the design of earthquake resistant buildings in Indonesia more rational with the use of local brick. The study was conducted using cyclic loading with the appropriate protocol to simulate earthquake loads on the model structure that has been scaled. To increase the low performance of confined masonry wall, bamboo strips were used as reinforcement for some models. The study discussed the value of R and Cd towards the Indonesian and developed countries code. The results showed the mechanical characteristics of local brick masonry with cement-based mortar is different from developed countries. The basic differences are the strength and stiffness of the local brick lower than mortar as a binder. This results showed that utilizing equations R and Cd from developed countries needed further attention for local brick masonry in Indonesia.

Peer-review under responsibility of organizing committee of the 2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials 2014

Keywords: confined masonry; Indonesian local brick masonry; cement based mortar

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Peer-review under responsibility of organizing committee of the 2nd International Conference on Sustainable Civil Engineering Structures and Construction Materials 2014
doi:10.1016/j.proeng.2014.12.176

1. Introduction

Indonesian local brick in masonry walls with a cement-based mortar has different physical and mechanical characteristics from the developed countries that are always used as references. The basic differences that should be concerned are the strength and stiffness of the local brick and mortar as a binder. The definition of local brick in Indonesia is a brick made by hand and with a burning furnace of shifting cultivation. Average compressive strength of the case for some local brick production areas in East Java Indonesia does not exceed 30 kg/cm^2 [1]. IBC [2] mentioned that the lower compression strength of clay brick is 1,700 psi or 119.6 kg/cm^2 and the lower compression strength of the masonry is 1,000 psi or 70.37 kg/cm^2. This clearly indicates that the brick strength from IBC larger than the brick and masonry strength in Indonesia.

The different behavior with another countries and low strength of local brick, it requires a lot of research to get the strength reduction factor (R) and the displacement amplification factor (Cd). To compute the design seismic force level for strength design, building codes allow the designer to reduce the elastic seismic force demand by a force reduction factor. The design displacements from an elastic analysis have to be amplified in order to estimate the actual deformations that may develop in severe earthquake, it is a displacement amplification factor. For this condition, it is important in order that the design of earthquake resistant buildings in Indonesia more rational with the use of local brick. Fig. 1 discribes the terms that will be used in this study [3].

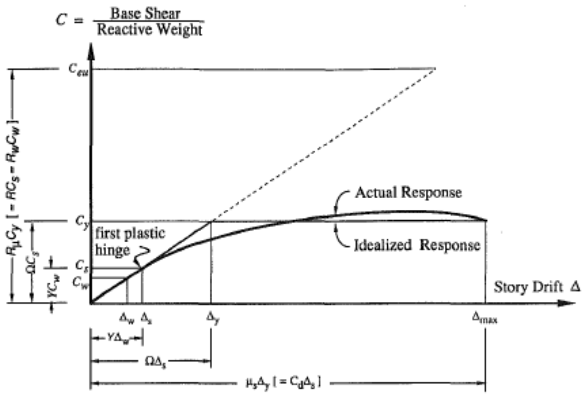

Fig. 1. General structural response [3].

SNI 1726:2012 [4] as code for design earthquake for buildings in Indonesia is mentioned response modifification coefisien (R) for special reinforcement clay brick masonry wall and plain clay brick wall masonry about 5 and 1.5 respectively. Deflection amplification factor is mentioned about 3.5 and 1.25. A detailed explanation of the types of masonry has not been mentioned in SNI code. ASCE 7-10 [5] Chapter 12 shows the same values as in SNI 1726:2012 [4] about strength reduction factor and amplification displacement factor. It shows the characteristic brick should be the same.

2. Research methodology

This study was conducted using cyclic loading with the appropriate protocol ASTM E 2126 [6] to simulate earthquake loads on the model structures that has been scaled. Scale model used is 1 : 2.3, model and prototype of clay brick is shown in Fig. 2. The confined masonry wall structures were made of local brick with physical and mechanical characteristics as well as the usual working methods in Indonesia and it is shown in Table 1. The confined masonry models were ready to be tested was shown in Fig. 3. Experiment setting up with cyclic loading was shown in Fig. 4.

Fig. 2. Comparison between the prototype and model local clay brick.

Fig. 3. Confined clay brick masonry ready for test in the laboratory.

Fig. 4. Setting up model on the frame for cyclic loading in the laboratory.

Table 1. Summary of mechanical characteristic confined masonry walls.

Parameters	Model	Prototype
Compressive strength of brick (ASTM) (kg/cm2)	18.78	20.94
Tensile spliting strength of brick (kg/cm2)	4.24	2.51
Compressive strength of mortar 1 PC : 5 Sand (kg/cm2)	50.54	-
Compressive strength of masonry wall ASTM (kg/cm2)	19.95	17.33
Compressive strength of confined concrete (kg/cm2)	173.08	-

3. Result and discussion

How to get the basic values strength reduction factor (R) and amplification displacement (C) used method from ref.[7] that shown in Fig. 5, Eq. (1) and Eq. (2).

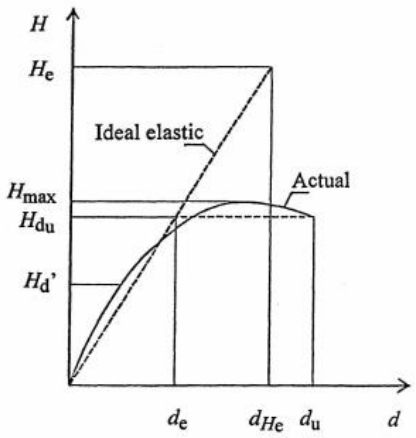

Fig. 5. Explanation of basic R and C [7].

$$q = \frac{H_e}{H_{du}} \qquad (1)$$

where H_e is the expected elastic load, H_{du} is the ultimate design load, and q is the behavior factor or basic value of R. Structural behavior factor can be also expressed in terms of the global ductility factor $\mu = d_u / d_e$. As shown in eq. 2.

$$q = (2\mu - 1)^{1/2} \qquad (2)$$

where q is the behavior factor and μ is the global ductility factor or basic value of C.

Result of experiment and calculation used Eq. (1) and (2) is shown in Table 2. Table 2 shows the global ductility factor or structural ductility factor for Indonesian confined masonry is about 2.2. Confined masonry with reinforcement that value can reach about 3.2. Behavior factor (q) for Indonesian confined masonry is 1.8, this value less than 2. Behavior factor for reinforcement confined masonry is about 2.3.

One example of the results of cyclic load test is shown in Fig. 6 and envelope of repeated load for all models is shown in Fig. 7. In Table 2 plain means confined masonry walls without reinforcemen and Reinf means confined masonry walls with reinforcement. The reinforcement are made from bamboo strips.

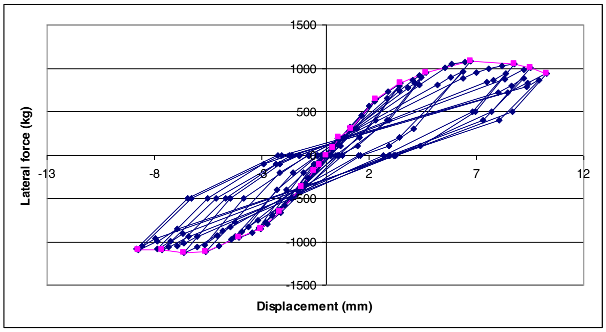

Fig. 6. Hysteritic curve and envelope model for masonry wall testing model Reinf 4-3.

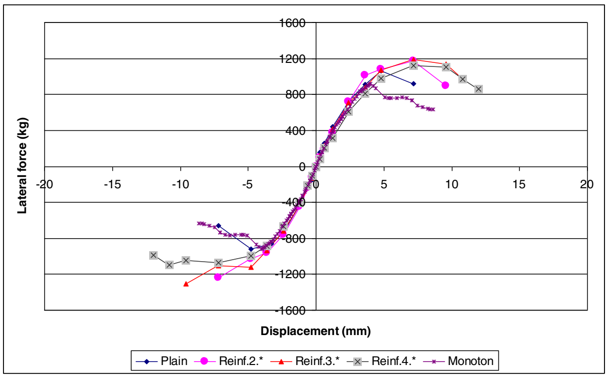

Fig. 7. Envelopes from hysteritic load masonry models.

Table 2. Global ductility factor (μ) and behavior factor (q)

Model	μ	q	μ (average)	q (average)
Plain 1	2.19	1.84		
Plain 2	2.69	2.09	2.24	1.86
Plain 3	1.83	1.63		
Reinf 2-1	2.84	2.16		
Reinf 2-1	2.45	1.97	2.44	1.97
Reinf 2-3	2.05	1.76		
Reinf 3-1	3.60	2.49		
Reinf 3-2	3.00	2.24	3.16	2.30
Reinf 3-3	2.89	2.18		
Reinf 4-1	3.65	2.51		
Reinf 4-2	3.61	2.49	3.28	2.35
Reinf 4-3	2.57	2.04		

Result of computation for strength reduction factor (R) and displacement amplification factor (Cd) are shown in Table 3. Rated of R is almost twice the value of q, as well as the value Cd close to twice the value of μ. Value of R from this research is bigger than ASCE 7-10 [5], but the strength of local brick is low, so it will be special attention for its use. Comparison of Cd to the R value is closer to 1, the same thing with the condition of the European countries that joined in the Eurocode [3]. The results of this study demonstrate research is still needed so that the values specified in SNI 1726-2012 can be used properly.

Table 3. Result of computation for strength reduction factor and displacement amplification factor and ratio Cd/R.

Model	R		Cd		Cd/R	
Plain 1	4.53		4.83		1.1	
Plain 2	4.60	4.24	4.90	4.43	1.1	1.0
Plain 3	3.60		3.54		1.0	
Reinf 2-1	4.36		5.04		1.2	
Reinf 2-2	3.47	4.56	3.79	5.03	1.1	1.1
Reinf 2-3	5.86		6.28		1.1	
Reinf 3-1	6.08		8.01		1.3	
Reinf 3-2	5.51	6.31	6.72	7.79	1.2	1.2
Reinf 3-3	7.35		8.63		1.2	
Reinf 4-1	6.68		8.24		1.2	
Reinf 4-2	7.52	7.19	10.00	9.00	1.3	1.3
Reinf 4-3	7.37		8.76		1.2	

4. Conclusions

The results showed the mechanical characteristics of local brick masonry with cement-based mortar is different with reference studies from developed countries. This results showed that utilizing equations from developed countries needed further attention. Based on R and Cd from this study, it is need to consider again the use of the values that comes from other countries for design earthquake in Indonesia or countries that have characteristics such as Indonesia. The test results showed a greater R value is associated with a low strength and low stiffness of the local brick masonry.

Acknowledgements

Present experimental work was carried out at Structure and Construction Materials Laboratory, Civil Engineering Department, University of Brawijaya, Malang, Indonesia.

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